The anisotropy of the resistivity and thermoelectric power in cubic ferromagnets U_3P_4 and U_3As_4

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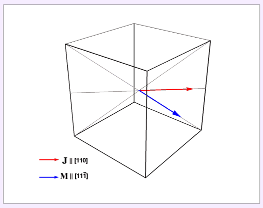
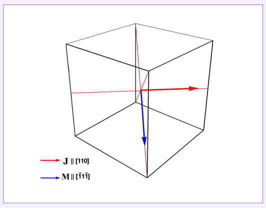
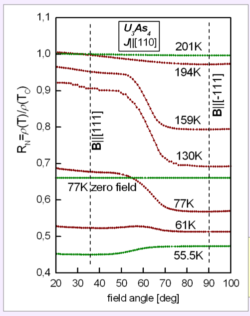
Both U_3As_4 and U_3P_4 are cubic ferromagnets with magnetic moments of uranium ordered along <111> and having values of $1.8\mu_B$ and $1.3\mu_B$, respectively.

Strong anisotropy of electrical resistivity exceeding 50% was observed in single-crystal samples of both compounds for data taken at different angles of external magnetic field. Such experimental conditions provide different angle between current and magnetization vectors.



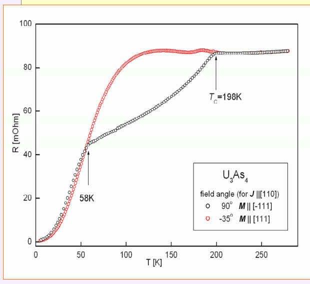


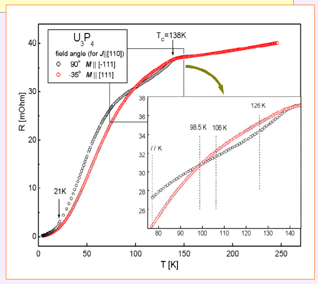


Field-angle dependence of the electrical resistivity of U_3As_4 at different temperatures (T_C =198K).

Unusual reversal of this anisotropy was discovered in both compounds when the temperature was decreased to about 55K and 100K, respectively. There is also a pronounced change in the slope of $R_{M||[-111]}(T)$ curve for U_3As_4 which coincides with the anisotropy inversion.

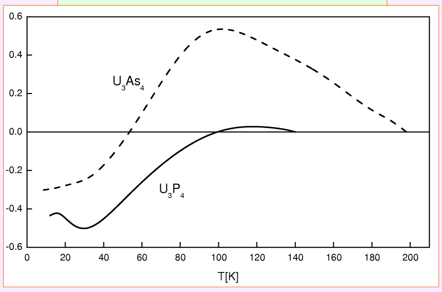
Temperature dependence of the electrical resistivity of U_3As_4 and U_3P_4 for two field angles.





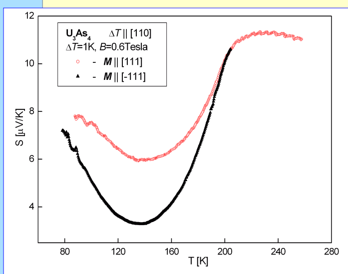
ferromagnetic anisotropy of resistivity (Ref. [4])

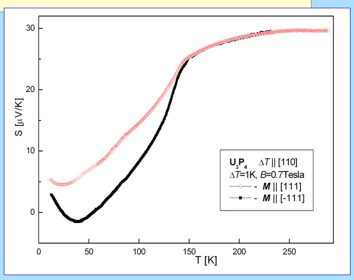
$$(R_{||}-R_{\perp})/R_{\perp}=(R_{M||[111]}-R_{M||[-111]})/R_{M||[-111]}$$

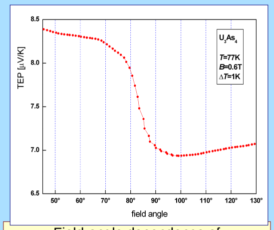


Even more striking is the analogous anisotropy of thermoelectric power which exceeds 100% for U_3P_4 and 80% for U_3As_4.
(in this case we have different angles between temperature gradient and magnetization vectors)

Temperature dependence of thermoelectric power of U_3As_4 and U_3P_4 for two field angles.

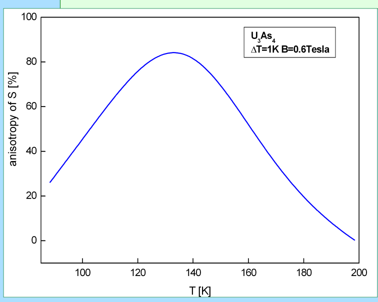


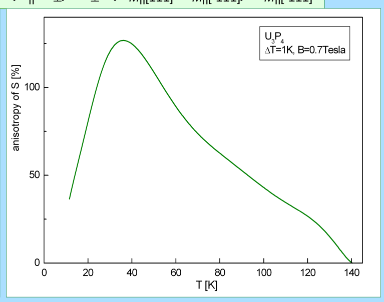




Field-angle dependence of thermoelectric power for U_3As_4 at 77K

ferromagnetic anisotropy of thermoelectric power $(S_{||}-S_{\perp})/S_{\perp}=(S_{M||[111]}-S_{M||[-111]})/S_{M||[-111]}$

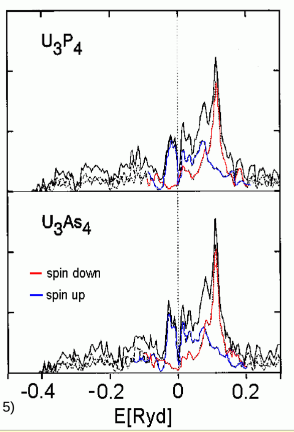




It is extremely unusual that application of weak magnetic field in specific direction causes such huge changes of thermoelectric power or electrical resistivity.

Anisotropy of resistivity in ferromagnetic Ni-alloys (reaching 15%) was described by Campbell, Fert and Jaoul [4] using a two-current model for spin-up and spin-down *s*-*d*-hybridised bands, with an essential anisotropy-inducing spin-orbit-coupling-driven interband mixing.

In this work, however we observe the anisotropy which is over three times stronger!



(from Ref. 5)

Electron-band calculations [5, 6] and de Haas-van Alphen measurements of the Fermi surfaces [7] (although done under assumption of cubic symmetry) hint a possible explanation for unusually strong resistivity anisotropy incorporating a two-current model of electrical conductivity taking into account 5*f*-bands with effective masses reaching 70 m_0 and 33 m_0 for U_3As_4 and U_3P_4, respectively.

First, there is a huge difference in density of spin-up and spin-down states in the vicinity of the Fermi level, particularly just under it. This makes perfect explanation for the sensivity of the resistivity to the magnetic field (magnetoresistance).

Second, spin-up and spin-down densities of states change abruptly just under and above Fermi level. It makes electron trasport properties extremely sensitive to any energy shifts of the conduction band. Obviously such a shift appears along <111> directions when the Fermi surface is deformed due to spontaneous rhomboedral distortion in magnetically odered state (magnetostriction of order of 10^{-3}) [1, 2].

From this point of view, the distortion induced anisotropy of the Fermi surface may be held mainly responsible for anisotropic electron transport properties in these compounds.

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